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Integration of Remote Sensing into Forensic Investigation

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Abstract
Forensic is the scientific method used to solve a crime governed by the legal standards of admissible evidence and criminal procedure. Forensic investigation is the gathering and analysis of all crime related physical evidence in order to come to a conclusion about a suspect, forensic in this research focuses on the presentation of evidence before a court of competent jurisdiction. Before the evidence can be presented to court, it has to pass through a process called chain of custody. This research is carried out in order to provide a platform for the integration of remote sensing into forensic investigation by focusing on evidence found in crime scene and geodetic data relating to the evidence.

Integration of remote sensing into forensic investigation is done using ArcGIS for geo-referencing and geo-coding, Microsoft Excel used for transporting data collected into ArcGIS and Garmin eTrex 10 GPS as a remote sensing device used to take coordinates. The system focuses on keeping track of chain of custody of evidence, keeping detail records regarding the evidence and location in which evidence were found, location through which evidence passes through (Chain of custody), geo-referencing of a map to show the whole area under consideration and geo-coding of the map with the geodetic data collected through the remote sensing device.

This study reveals that integration of thematic map of region under consideration gives adequate description and location of the evidence and chain of custody and further present firsthand information to local authorities, forensic investigators and jury about the chain of custody.

Keywords: *Forensics, Forensic Investigation, Remote Sensing, Geo-referencing, GIS, Geo-coding, geodetic data, chain of custody*

INTRODUCTION

Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object. Forensic is the scientific method used to solve a crime governed by the legal standards of admissible evidence and criminal procedure. Forensic investigation is the

gathering and analysis of all crimes related physical evidence in order to come to a conclusion about a suspect. Investigators will look at blood, fluid, or fingerprints, residue, hard drives, computers, or other technology in order to establish why, when, how and where a crime took place.

From the definitions above, it is obvious that there are undefined relationships between remote sensing and forensic. The relationship can be clearly and appropriately defined if remote sensing technology is integrated to forensic investigation, which will provide a basic understanding of concepts involved in the use of remote sensing devices and software with emphasis on geo-coding and Global Positioning System (GPS). This will help resolve controversy in the investigation surrounding the area or location where a crime took place and the various places evidence or exhibits passed through before they are presented in the court.

Crime scene investigation and evidence collection basically entails locating, identifying, collecting, and cataloging evidence collected at the scene of crime. Such evidence can be tampered with during the course of transferring from one point to another during the cause of investigation if not properly documented, monitored and the various places it passed through accurately recorded for proper accountability. When evidence is first found on a crime scene, steps have to be taken to document where that evidence was found and subsequent places it will pass through before its final destination which is presentation in court. This is usually done with crime scene photographs and notes taken during the initial investigation. Most police agencies, private investigators and crime laboratory will label items of evidence with a number and record its location which may not be precise and adequate enough to give meaningful description to a third party and interested individual who was not at the scene of the crime and ineffective should in case natural disaster or changes occur within the vicinity in which the evidence was found or collected. Remote sensing integration into investigation process will help indicate the exact point where evidence was found and also keep digital records of locations and create a mapping of chain of custody.

Remote sensing method used in this study is based on making direct measurements of the surface of the earth in order to determine location of evidence by taking its coordinates and also keep records of prints (finger prints) and other objects left behind in the crime scene for further study such as laboratory research in order to carry out pattern match. The resulting measurement information can be presented in either an imaging format such as in aerial photography or a non-imaging format, such as in a profile or contour map. These measurements can be interpreted to identify and characterize contrasts due to differences in physical and natural properties of the evidence being studied. Therefore this research is carried out to provide a basis for the inclusion of location of where a crime took place and other relevant locations in the investigation process by using remote sensing.

Problems Identification

The following problems were identified in an existing investigative system;

1. Poor/lack of remote sensing in the forensic investigation process.
2. Lack of proper data management system.
3. Assumption of location where evidence was collected for accurate record.
4. Improper recording of chain of custody.

Objectives

The primary objective of this research is to integrate remote sensing into forensic investigation in order to have and maintain a well-documented and accurate chain of custody. Other objectives are to;

1. give accurate and current information about crime scene;
2. provide precise and detail chain of custody;
3. present coordinate systems that will facilitate integration of datasets to perform various integrated analytical operations of all locations specified in the chain of custody and
4. improve cataloguing of evidence and geodetic data

Review of Existing Works

The use of remote sensing techniques has largely proved to support and improve the analyses of evidence in crime scene such as *fragile or transient evidence and solid or tangible evidence.* The capability of collecting multiple data source on very large areas and the development of processing techniques had resulted to failure due to changes which may occur within that space of investigation and their presentation before a court and some period of time. Remote sensing and integration of GPS and GIS into investigation may help locate exact location on earth where evidence were found by getting the elevation, longitude and latitude of that point known as coordinates, which may be later used if the need be to study the points for further analytical operations in the course of the investigation.

Remote sensing has been successfully applied in different fields and areas and such cases are examined hereafter;

(7) adopted NDVI technology for extracting the various features presented in the 3-band Satellite image of VELLORE district. This journal shows how the differences between the visible red and near-infrared (NIR) bands of an INSAT image can be used to identify areas containing significant vegetation and other different features. The forests are combined with areas of grass and mountain Vegetation. Landsat TM / ETM images were rectified and projected to Universal Transverse Mercator (UTM). Interpretations of land use / land cover were done with image contrast technique using ERDAS IMAGINE software. The weaknesses of this research are;

i. this approach couldn't be used for forensic investigation, the NVDI technology can't be adopted in locating coordinate and

ii. the GIS software adopted in this research couldn't be efficiently used in forensic investigation because it can't be used in mapping various geographic features on the earth as raster and vector data. This makes it impossible to record its chain of custody.

Therefore it is necessary to develop a means by which remote sensing can be integrated into forensic investigation.

(4) established a process for cyber-crimes investigation through digital forensics. This research focused on creating a digital forensics framework from which a detailed methodology was derived to be used by digital forensics experts in the field when investigating cyber related crimes.

The research helps experts in the field to combine methods, both qualitative and quantitative in order to develop a common code of practice for the digital forensic community and devised a comprehensive methodology that will allow computer forensics practitioner to capture and preserve digital evidence acquired adequately, keeping in mind the volatility of the data but did not integrate the use of remote sensing

(10) used land use/land cover accuracy assessment carried out using satellite image of a particular mapped out region gotten through the satellite over Google map because different zones within the region are to be assessed, assessment is carried out using the ERDAS IMAGINE 2015 software and signature of different zones are recorded in tabular form. The weaknesses of this research are;

i. this approach couldn't be applied in forensic investigation because a satellite view image of a region cannot be used to keep track of location of chain of custody which would give no meaning to third party;
ii. the GIS architecture used in this journal could not keep track of multiple location which will not be helpful in mapping them together to form the chain of custody and
iii. region was considered over location in this journal which makes it irrelevant in forensic investigation.

The approach used in this research was unable to fully integrate remote sensing into forensic investigation. Therefore it is important to develop an approach and a system that can take forensic investigation into consideration.

According to (3), The Geographic Information System (GIS) and the Global Positioning System (GPS) are the two geospatial technologies that are being used in monitoring of transportation generally. Transportation is a requirement for every nation regardless of its industrial capacity, political stability, population, size or technological development. This study integrated GIS and geospatial technology to enhance road safety
The contributions of the study are:

i. geospatial technologies were used to generate a digital map of Nigeria roads;
ii. it provides a platform and point of location for incidences that may occur on the road and
iii. it established a means to ensure easy location of vehicles and incidents on roads.

This study clearly showed that remote sensing could be used for identification and locational purposes

Furthermore, (1) integrated remote sensing into soil classification. The research used remote sensing in the reconnaissance soil fertility study of 10,000 ha partly encroached forest reserve located between latitude 11°47'N and 11°56'N and longitude 4°22'E and 4°32'E in Northern Nigeria that was conducted in 2009 to generate a soil fertility data base of the reserve. The tracking of the forest reserve boundary was done using a Garmin 72 model global positioning system (GPS) receiver. The geographic coordinates were input into the computer to generate a digital map of the forest reserve. The entire forest reserve was divided into grids to guide in the location for soil sampling using the GPS/Geographic Information System (GIS) geospatial technique. Soil auger studies were made at 250 locations to site 60 sampling pits to collect soil samples for laboratory analysis of soil properties.

(2,8,9,&11)clearly and practically demonstrated that remote sensing could be integrated to locate objects on the soil, under the soil and on water.

Methodology

The proposed system is to help capture, record and process the exact location (longitude and latitude) where particular evidence was found and collected by using a GPS device for capturing the coordinates and processing it to generate a digital map of chain of location. These coordinates and details concerned with their relevant information were recorded in a Microsoft Excel spreadsheet for documentation, thereafter, this documentation stored in spreadsheet were imported into the ArcGIS software where geo-coding and geo-referencing operations were performed on the dataset to get a base map of locations as stored in the spreadsheet. All these involved these three processes:

i. GPS/ Geo Spatial technology
ii. Geo-coding
iii. GIS

Global Positioning System (GPS)

Global Positioning System is a global navigation satellite system that provides location, velocity and time synchronization. Nowadays GPS is everywhere and it can be found in a car, smartphone and even watch. GPS helps to locate and get to destination; from point A to point B. GPS technology has been used globally throughout history. The launch of Russia's Sputnik I satellite in 1957 ushered in the possibility of geo-location capabilities and soon after, the U.S. Department of Defense began using it for submarine navigation. In 1983, the U.S. government made GPS publically available, but still kept control of the available data. It wasn't until 2000 that companies and the general public gained full access to the use of GPS. GPS satellites provide service to civilian and military users. The civilian service is freely available to all users on a continuous, worldwide basis. The military service is available to U.S. and allied armed forces as well as approved Government agencies.

GPS works through a technique called trilateration - a mathematical technique used by a Global Positioning System (GPS) device to determine user position, speed, and elevation. These are used to calculate location, velocity and elevation, trilateration collects signals from satellites to output location information. Satellites orbiting the earth send signals to be read and interpreted by a GPS device, situated on or near the earth's surface. To calculate location, a GPS device must be able to read the signal from at least four satellites. Each satellite in the network circles the earth twice a day, and each satellite sends a unique signal, orbital parameters and time. At any given moment, a GPS device can read the signals from six or more satellites. When a satellite sends a signal, it creates a circle with a radius measured from the GPS device to the satellite. When we add a second satellite, it creates a second circle, and the location is narrowed down to one of two points where the circles intersect. With a third satellite, the device's location can finally be determined, as the device is at the intersection of all three circles.

This process gives a three-dimensional output, which means that each satellite produces a sphere, not a circle. The intersection of three spheres produces two points of intersection, so the point nearest Earth is chosen.

The five main uses of GPS are:

Location: Determining a position.

Navigation: Getting from one location to another.

Tracking: Monitoring object or personal movement.

Mapping: Creating maps of the world.

Timing: Making it possible to make precise time measurements

Geo-coding

This is the process of transforming a description of a location such as a pair of coordinates, an address, or a name of a place to a location on the earth's surface. This can be done by entering one location description at a time or by providing many of them at once in a table. Geo coding simply involve taking a text-based description of a location, such as an address or the name of a place, and returning geographic coordinates, frequently latitude/longitude pair, to identify a location on the Earth's surface

Three main methods of geo-coding are available by:

- street address,
- postal code; and.
- boundary.

Geographic Information System (GIS)

A geographic information system (*GIS*) is a framework for gathering, managing, and analyzing data. Rooted in the science of geography, *GIS* integrates many types of data. It analyzes spatial location and organizes layers of information into visualizations using maps and 3D scenes. GIS applications include both hardware and software systems. The key word to this technology is Geography – this means that some portion of the data is spatial. These applications may include cartographic data, photographic data, digital data, or data in spreadsheets. An example of this kind of information is computer data collected by satellites that show land use i.e the location of farms, towns, and forests

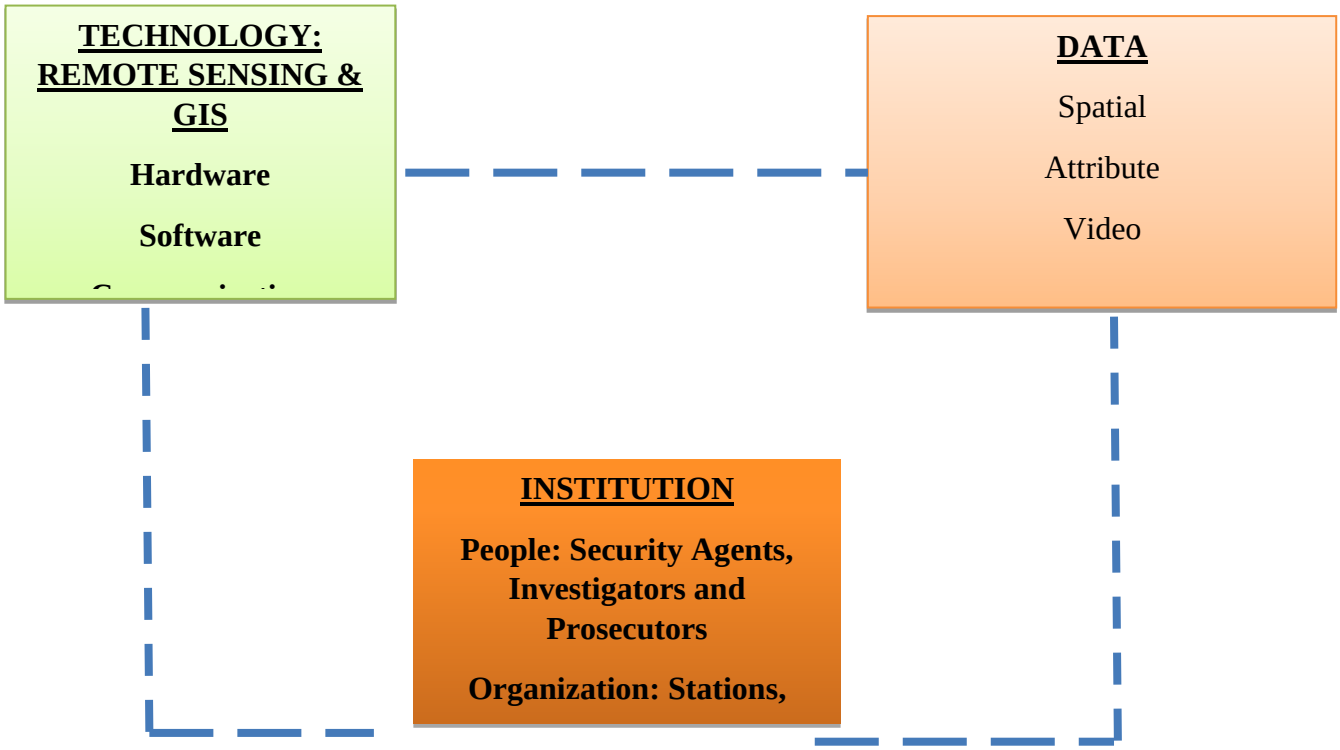

Fig. 1. Components of Integration

Implementation and Result

The steps involved in integrating remote sensing into forensic investigation are
Identification of locations (obtain chain of custody)
Take the coordinates of the locations
Geo-coding the locations
Export result to ArcGIS
These steps can be demonstrated using a real life example as stated below with its test results of a case involving several individuals with a theft of a stolen system. The system was similarly discussed in (5) and (6)
An illustration of a car stolen in Ilesha, Osun state Nigeria which passed through many states before the culprit was found in Nassarawa state, where the stolen system was confiscated and taken to Ogun state for cataloging for further investigation. The stolen car was tracked through different states with the help of a tracker installed in the car by its owner and each location the car was tracked through was documented and recorded. The procedures stated below were used in tracking and securing the car.

1. Locate the origin of the crime scene in order to create a meaningful and accurate chain of custody. After locating the particular place the crime was committed, and where the chain of incidence commences, coordinates of the scene and other places recorded by the tracker were taken using a GPS receiver.

2. Record the geodetic data into a spreadsheet. Coordinates were recorded in X, Y axis and other notable features about evidence were recorded in other columns, this involved the conversion of these coordinates obtained in geodetic system to UTM system.

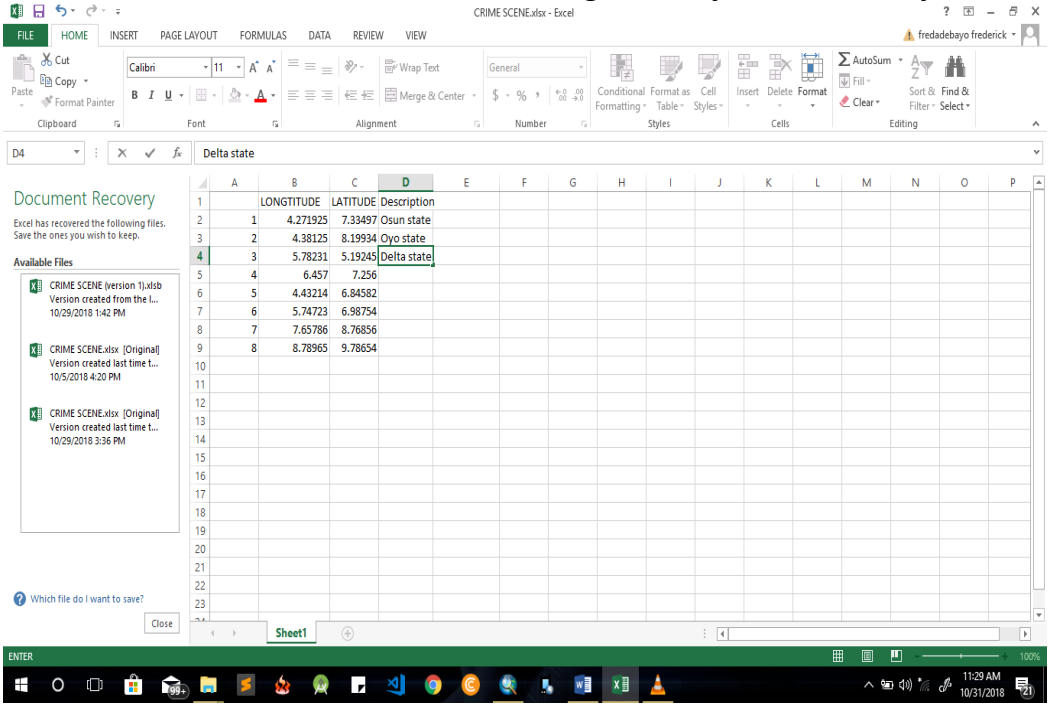

Figure 2.0. A spreadsheet image of coordinate and description of chain of custody

Repeat this step for every location in which the evidence passes through up to N, in which N represent the numbers of places evidence passes through.

3. Save the spreadsheet document in a directory that can be easily accessed through the ArcGIS.

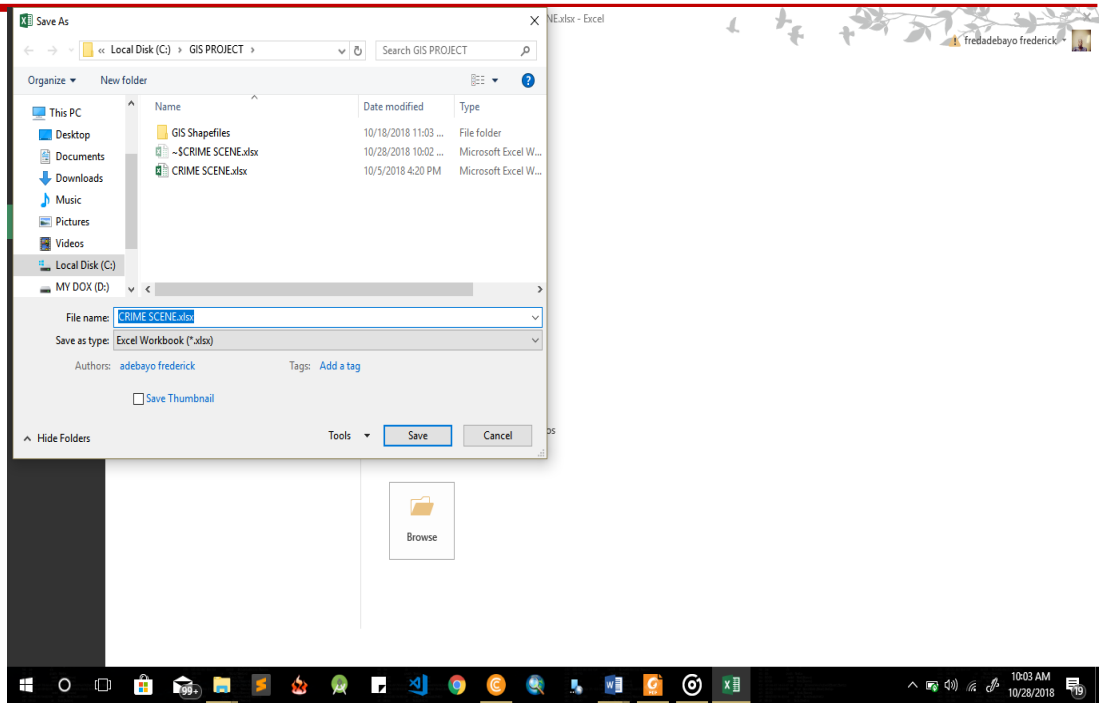

Figure 3.0. Image of coordinate spreadsheet document saved in the ArcGIS directory

4. Open the ArcGIS software and create a new project using a blank map template as start up.

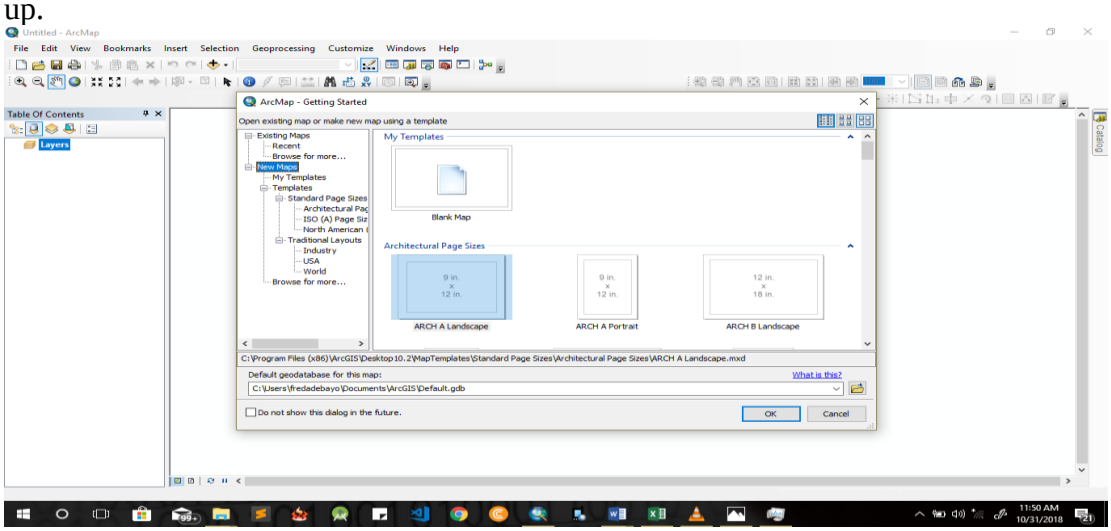

Figure 4.0: Shows interface of new project on ArcGIS using Blank map template

5. The fifth major step is geo referencing which is the application of GIS software ArcGIS to geo-reference.

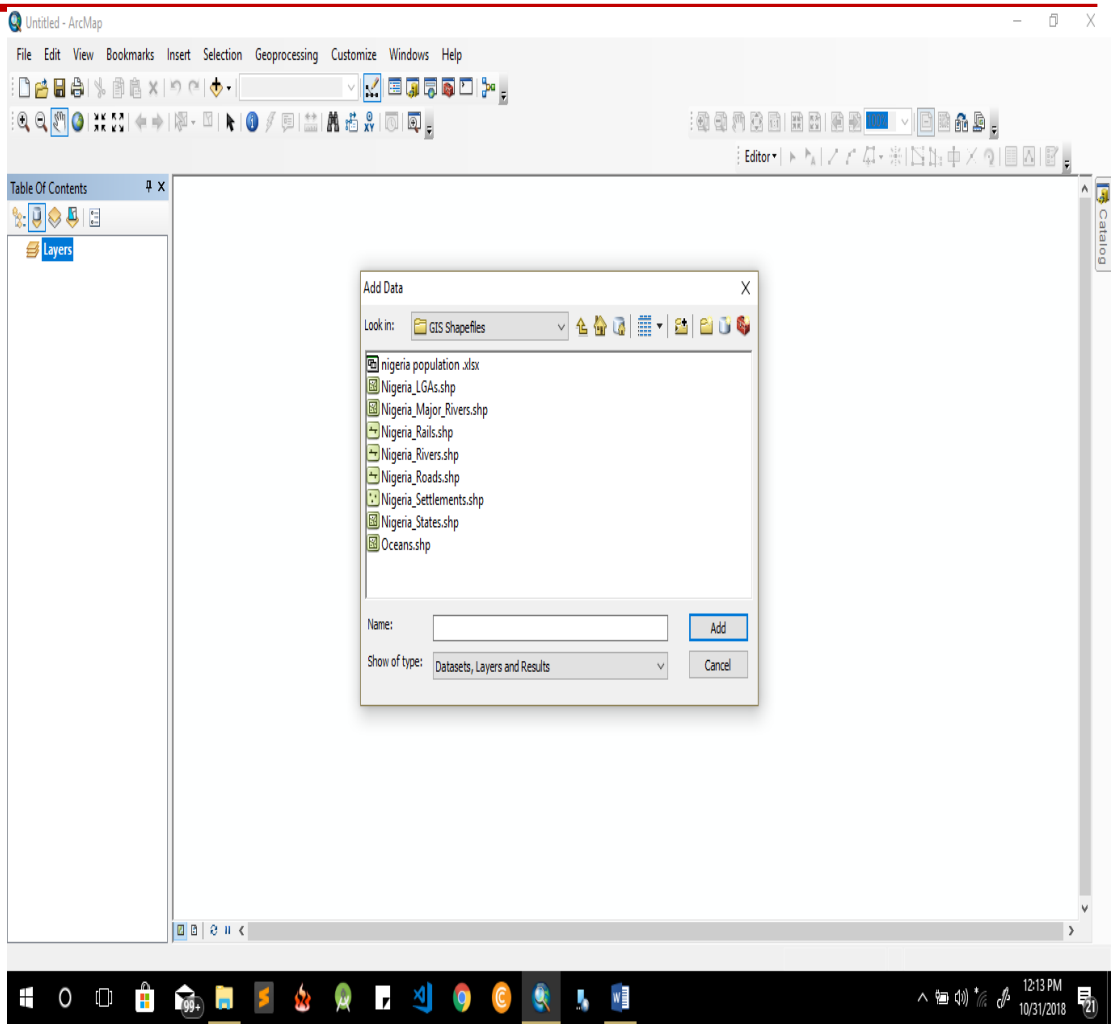

Figure 5.0. Shows map files in the ArcGIS directory

6. Import the saved spreadsheet document into the ArcGIS.

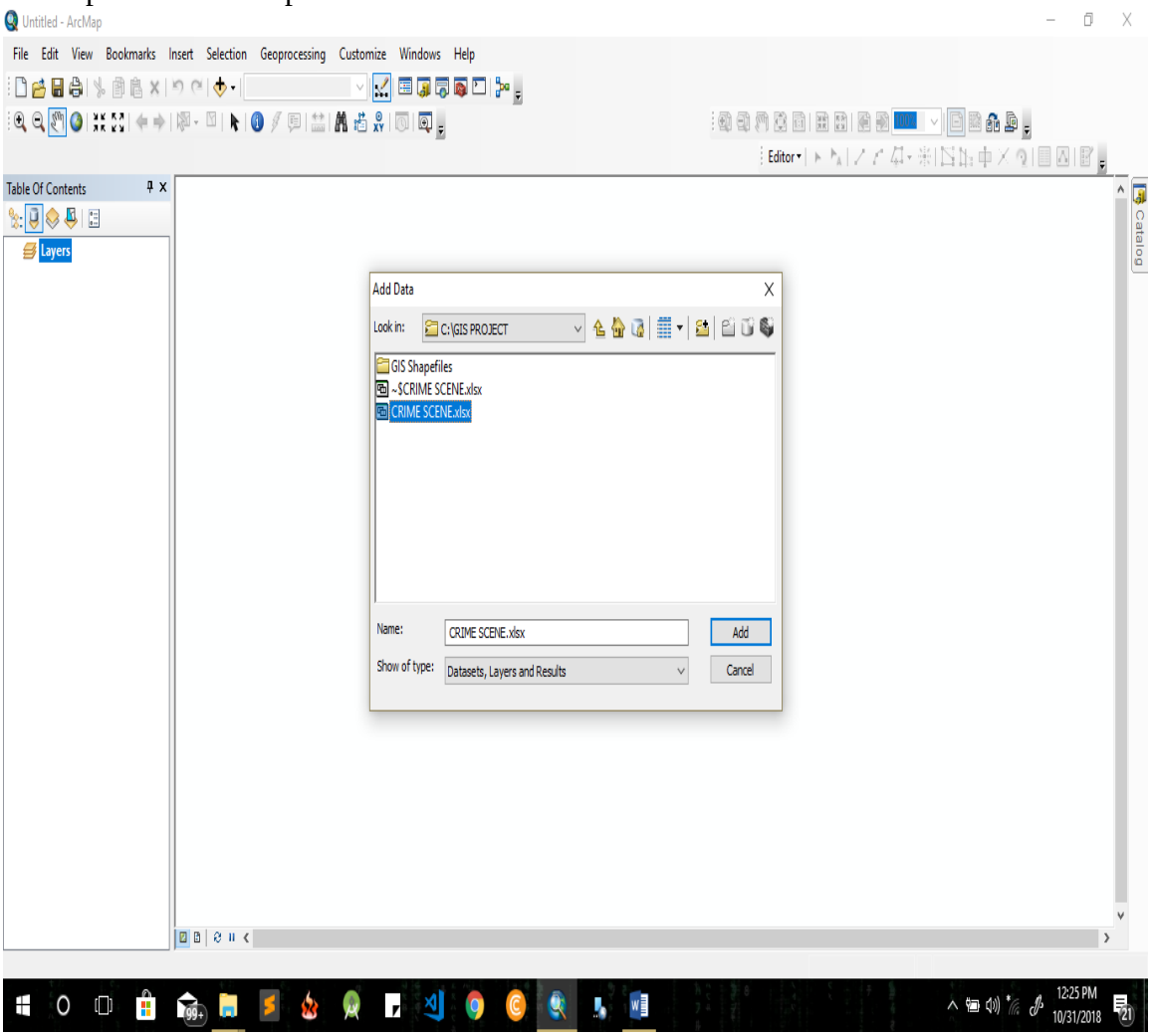

Figure 6.0. Shows coordinate files saved in the ArcGIS directory

7. Geo-code the spreadsheet document in order to help represent the geodetic data over the imported map.

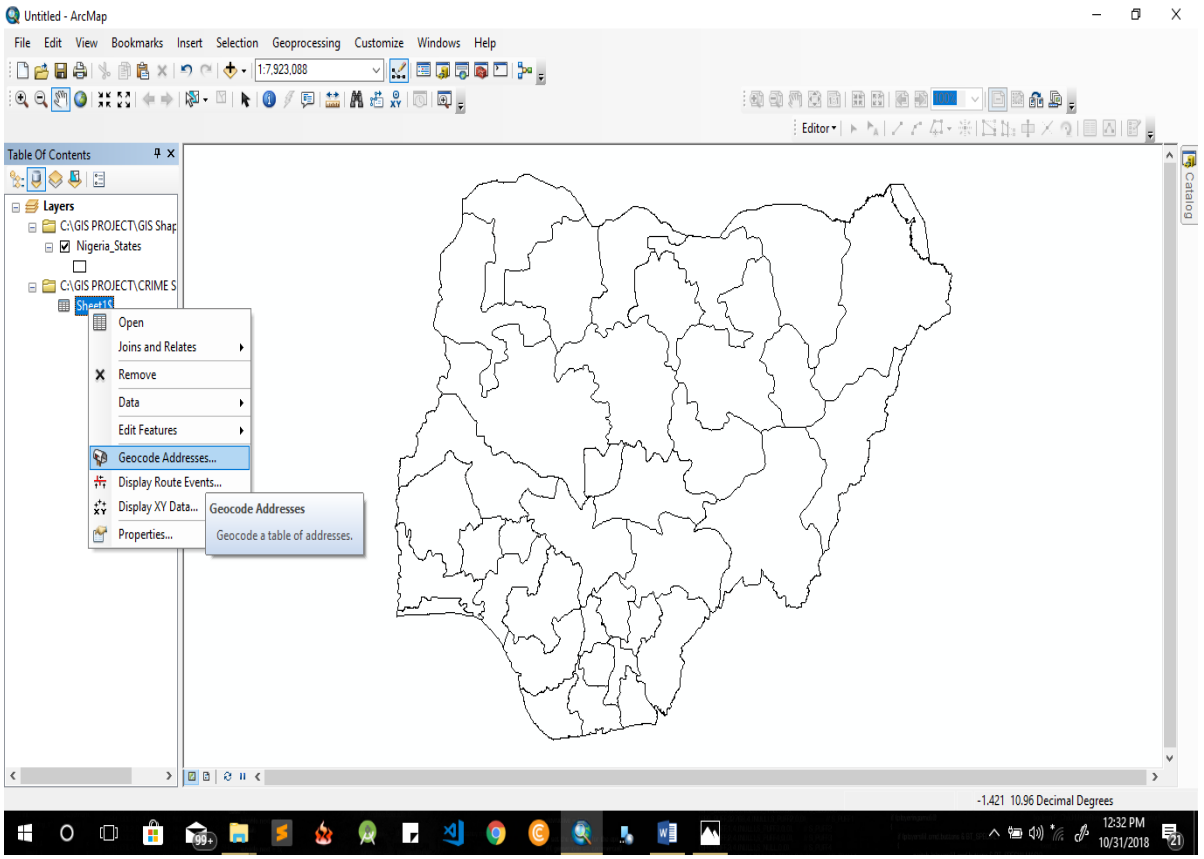

Figure 7.0. Shows area under consideration after geo-coding

8. Export the map into any desired image format and present the image as case result for the ongoing investigation.

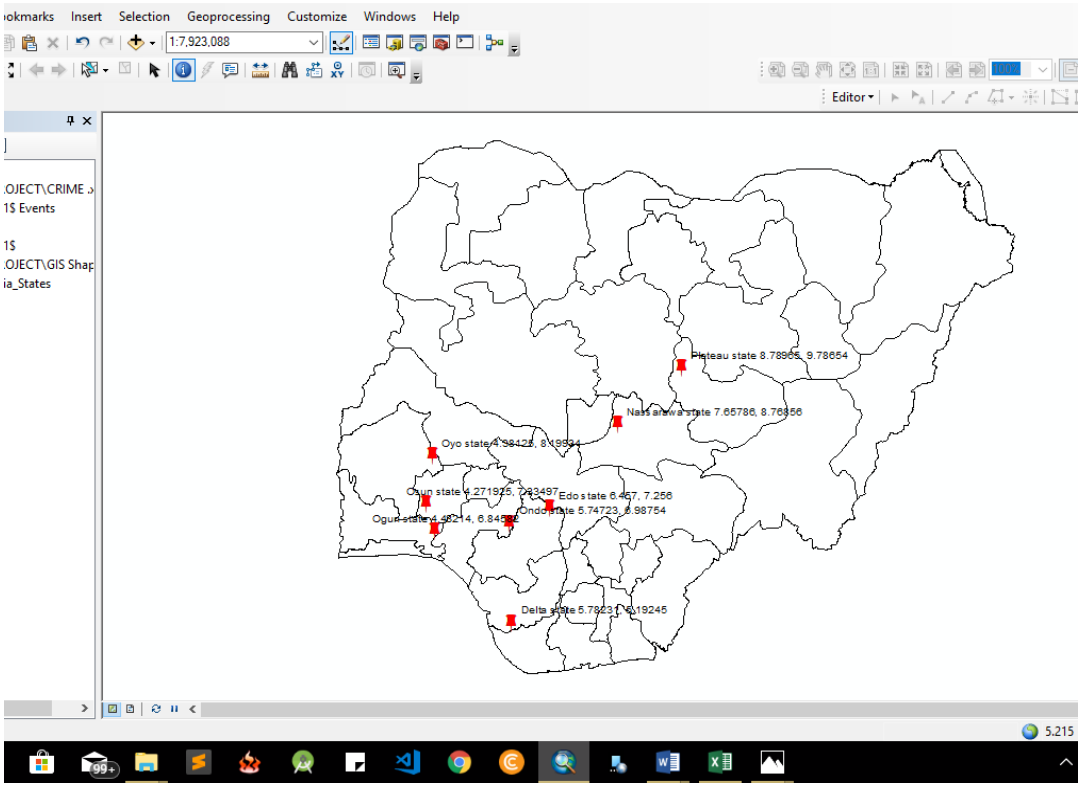

Figure 8.0. Shows of map of the area

The below table shows the chain of custody of the confiscated evidence

1	Osun state
2	Ondo State
3	Edo state
4	Delta state
5	Plateau state
6	Nassarawa state
7	Oyo state
8	Ogun state

CONCLUSION

In this research, spatial technology had successfully been integrated into forensic investigation. This was achieved by using GPS device to take the coordinates of scene of crime, points where evidence were collected and the various locations the evidence passed through during the course of investigation. The coordinates were exported by Microsoft Excel to ArcGIS for mapping and other analytical operations. This process was demonstrated using real life data and was successfully implemented. The two spatial technology used which are Geographical Information System and remote sensing have proved to be powerful, accurate and cost effective method for determining locations of scene of crime, actual point where evidence where found, kept and passed through during forensic investigation. The study reveals that integration of thematic map of region under consideration gives accurate and up to date information to local authorities, forensic investigators and jury about the scene of crime, point where evidence was collected and the various locations the evidence passed through during the course of investigation which is known as chain of custody.

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